URINARY CALCULI: THEIR FORMATION AND STRUCTURE.[1]

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HAVING commenced my medical career as an apprentice at Norwich, and as a pupil at the Norwich Hospital, my thoughts were early directed to the subject of urinary calculus, particularly in its practical bearings; and for many years subsequently I had much experience in the treatment of stone in Addenbrooke's Hospital. It is not, however, my intention to take you at any length over the well-trodden ground of the treatment of this malady, but rather to discuss for a short time the structure and mode of formation, or building up, of stones in the bladder and some of the forms they assume, matters which, I think, have some interest and some difficulties, and which have not received much attention. I do not mean the microscopical constitution or the chemical composition, but rather the more obvious physical structure, of calculi. For this purpose I have gone, more or less carefully, over nearly all the collections in London as well as that in Norwich, and that in our own museum here. I do not wish by this to raise your expectations of what I have to say, for I must confess to being not very proud of my results in ascertaining the causes of the peculiarities which some calculi exhibit, and I am reluctantly obliged to leave many of these points to the more fertile reflections of yourselves and others.

Let me first draw your attention to a few remarkable specimens. I show you here one of the largest calculi which has been found in the human bladder, and which presents some points of historic and collegiate, as well as of clinical, interest. According to an account of it by Dr Heberden given in the *Philosophical Transactions*[2] it weighed thirty-three ounces and three drachms, and was taken after death from the wife of a locksmith at Bury St Edmunds. It was shown to Charles II. at one of his visits to Newmarket, "when at least half an ounce was broken off before the king to show him that it was formed in the manner animal stones usually are." It was of an "oval shape, flattened on one side and its surface smooth." The specific gravity was 1·75. It was presented to Trinity College, Cambridge, by Mr Samuel Battely, Member of Parliament for Bury St Edmunds, about the middle of the reign of Queen Anne, and was preserved in the library of that College, together with other calculi, a human skeleton, and a curious assortment of animal and other specimens, indicating that the studies at the College were not limited to books and stars, philosophy and casuistry, but were to be extended, practically, to the various regions of science. Reminders of this, and also of the fact that

[1] An address delivered at the Summer School of Medicine for Qualified Practitioners in Cambridge, June 1895.

[2] *Philosophical Transactions*, 1723, vol. xlvi.

libraries were the only museums of that time, are still given by a human skeleton in the library at Queen's College, and by one in the library at Jesus College. About thirty years ago the calculus and its companion specimens were transferred to the pathological museum of the university. It is of clinical interest forasmuch as we learn that "the woman had felt much less pain than might have been expected from so large a stone, and might probably have lived much longer with it had she not thought herself well enough to attempt a journey on horseback; for, while she was riding, she was suddenly seized with violent pains that obliged her to be taken off the horse immediately. After this she could never make water unless the stone was first moved, and she continued in great agonies till her death." This corresponds with the fact that the stone is of very compact structure, composed chiefly of concentric layers of uric acid with some oxalate of lime and a thin coating of fusible calculus. It measures 15 in. by 13½ in.[1] It formed, no doubt, very slowly during many years (we cannot tell how many, for estimates as to the rate of growth of calculi are little more than guesses) in the bladder which gradually became accustomed to it and did not resent its presence or object to its weight. Hence, the comparatively little suffering and the long duration of life. In the Norwich collection there is a six-ounce phosphatic calculus which was less meekly tolerated by the female bladder, for it is said to have been ejected spontaneously through the urethra. A still larger stone, weighing forty-four ounces, taken after death from the bladder of Sir Walter Ogilvie, is in the museum of the Royal College of Surgeons of England. He had paraplegia, and the stone is phosphatic. A calculus in St Thomas's Hospital museum weighing twenty-five ounces was, at about the same date as the large one I have shown you, taken after death from Sir Thomas Adams, the philanthropist, draper, Lord Mayor of London, president of St Thomas's Hospital, and the intimate friend of Charles II., to whom he contributed large sums of money, and who created him a baronet, and for his loyalty to whom he was imprisoned in the Tower. He was educated at Cambridge, and founded the Professorship of Arabic in this University in 1632. The calculus resembles the one I have shown you, being composed of compact and regularly laminated uric acid formed around an oval nucleus of more porous uric acid. It appears to have caused little pain or inflammation of the bladder or disturbance of the general health, and, finally, to have proved fatal in consequence of a fall which the worthy baronet had, at the age of eighty-one, in descending from his carriage. It presents a groove dividing it into two unequal parts. This groove, which was probably caused by the projecting hinder edge of the trigone of the bladder, is deep, and with defined edges on what we may suppose to have been the under part of the stone, and becomes shallower and gradually disappears towards the upper part. In a sermon preached "at the solemnity of his [Sir Thomas Adams's] funeral" on March 10th,

[1] See analysis and drawings by Professor Cumming in the first volume of the Cambridge *Philosophical Transactions*.

1667, the groove is described as being, "as it were, a paved way, or rather a channel cut through the stone, for his water to pass," otherwise "the stoppage of it must of necessity have very much added to his smart and lessened his days." The stone is rather uneven and slightly rough on the exterior, being covered, as these large calculi not infrequently are, with a layer of more porous uric acid or urate of ammonia. This coating extends over the groove as well as over the rest of the calculus. A drawing of the calculus, with other particulars respecting it and Sir Thomas Adams, is given in vol. xxi. of the *Transactions of the Pathological Society* by Mr Charles Williams of Norwich, to whom I am indebted for a loan of the sermon.

The largest stone which has, I believe, been removed entire and successfully by the lateral operation is in the Norwich collection. It weighs fifteen ounces, and was extracted by Mr Harmer, a Norfolk surgeon, in the presence and with the aid of Gooch, who gives a representation of it in his work on Surgery. A urinary fistula remained, which Gooch says was kept clean by a little dog licking the part, which gave the patient more ease than any application his surgeon furnished him, and as long as he lived (five years) the dog was his surgeon and kept the wound tolerably clean and easy. The next largest, so far as I know, removed successfully and entire by the lateral operation, is in the museum at St George's Hospital. It weighs eleven ounces, is composed in its middle of uric acid and some oxalate of lime, with a thick coating of compact, concentrically marked phosphate of lime. It was extracted from a man aged forty-three, with much difficulty, by Mr Warrington Haward, in St George's Hospital, who found it necessary to extend the incision into the rectum. A fistula remained, in this case as in the preceding one, but the man was alive and, with that exception, well some years afterwards. In the museum at Guy's Hospital is one weighing thirteen ounces extracted successfully by Mr Mayo of Winchester, but it broke and was removed in fragments. One in the same museum weighing nine ounces was successfully removed by Sir A. Cooper, and another weighing sixteen ounces was also removed entire by the same surgeon, but the patient sank. In the museum of the Royal College of Surgeons of England there is a still larger calculus, the largest, I imagine, which has been removed by the lateral operation. It was dragged through the perineum by Cheselden, and weighed seventeen ounces, but the patient sank the next day. One weighing thirteen ounces failed to be extracted by Mr Dalrymple of Norwich. The largest which I have seen extracted is the uric-acid calculus I show you, weighing eight ounces, which I removed, by means of a strong scoop, through the perineum of a man in the neighbourhood of Newmarket. He recovered without a bad symptom.

On looking over the Norwich collection one is struck with the number of large calculi which have been removed successfully by the lateral operation, and which bear testimony to the reputation as lithotomists which the surgeons of that city have long held. Most

of them are sound, hard, uric-acid stones, and, so far, tell of the sound constitution of the patients, contrasting with these nine calculi from India, sent us by a former pupil, which, though containing uric acid and oxalate nuclei, are, for the most part, composed of phosphates. There is a phosphatic calculus from a negro in the museum of King's College Hospital, and a calculus weighing three ounces and a half, apparently phosphatic, with curious projecting knobs, in the museum of St George's Hospital. It was removed by the lateral operation from a man who had spent the greater part of his life in India. He did not recover. In the museum at St Mary's Hospital there is a phosphatic calculus from India, with two concentrically marked, apparently uric-acid nuclei as large as filberts joined by a band like the Siamese twins. There are, however, in the museum of St George's Hospital two oxalate of lime calculi from India, and in the Royal College of Surgeons of England there is a collection of many calculi, removed by operation from Hindoos and Afghans, which are composed apparently of uric acid; they are compact and present the usual concentric rings. Thus we see that the inhabitants of that region of the world, who are mostly vegetable-eaters, are liable to the same varieties of calculus as our own countrymen. The oxalate of lime is said by Castor to be a more frequent nucleus than uric acid in India, and is attributed by him to the vegetable character of the diet.[1] This fine bristling specimen of oxalate of lime weighing four ounces—a good example of the *calculus spinosus* of Celsus—was successfully removed by myself from a middle-aged man. The largest example of this variety of calculus which I have seen weighed eight ounces. It is in the Royal College of Surgeons of England and was removed from a man in Norfolk aged sixty, who appears to have gone on well for six weeks, but then to have become depressed and sank. These results of the lateral operation pale, however, in interest since the revival, under antiseptic advantages, of the supra-pubic method, by which great stones have recently been removed with success and without much difficulty. In the Royal College of Surgeons of England there is a calculus weighing thirty-four ounces and a half, six inches long, and four inches in diameter, which was removed at Cairo by Mr Milton, by the supra-pubic operation, from an Egyptian fellah, aged sixty, who was at the time in bad health. The operation is described as one of "laparotomy," for the peritoneum, as well as the bladder, was opened above the pubes. The man lived two months and a half and then died from kidney disease.[2] In Ashhurst's *International Cyclopædia of Surgery*, vol. vi. p. 162, a case is quoted in which a stone, weighing forty ounces and a half, and measuring seventeen inches in circumference, was removed from a man aged thirty-nine, by the supra-pubic method, by a Brussels surgeon, the patient dying eight days afterwards. This is probably the largest stone ever removed from the living human bladder. It is somewhat strange, and not particularly creditable to

[1] Ashhurst: *International Encyclopædia of Surgery* vi. 160.
[2] *The Lancet*, Sept. 16, 1893.

me, that, having tested this method in 1848 on a lad aged fourteen who had shown symptoms from birth,[1] I should not again have resorted to it till within the last few years, when it had been revived by others, especially as the case taught me that I over-estimated the ill-effects that were likely to result from extravasation of urine into the loose tissue about the bladder. I carefully emptied that viscus before the operation, instead of washing it out, and perhaps filling it with antiseptic fluid, as is now done. Yet, in spite of my precautions, when I cut into the bladder, to my dismay a considerable quantity of urine (pent up, I suppose, in the ureters, as may be seen to have occurred in a specimen in the Middlesex Hospital, where, with a calculus in the bladder, the ureters, pelves, and calices of the kidneys are enormously dilated) flowed out and soaked into the surrounding tissues; yet no ill resulted. The thickened bladder had misled me somewhat as to the size of the stone which, as you see, is not very large, and weighed only 750 grains. The lad made a good recovery; and some time afterwards I extracted, by the lateral method, a stone which had formed upon and was adherent to the cicatrix of the former operation.

The nucleus.—The nucleus, which is the incipient or foundation, and usually the central part, is obviously the most important part of a calculus, that to which attention has been most especially directed. It commonly forms in the kidney and consists of uric acid, oxalate of lime, or cystine—of the first most frequently, of the last rarely. Its formation depends upon one or both of two causes: first, an unusual quantity of one of the more easily precipitable constituents of the urine (uric acid or oxalate of lime), when a very slight cause will lead to the precipitation and union of the crystals, which may take place in the uriniferous tubes or in the calices of the kidney; secondly, a slight increase, or alteration in the quality of the mucus in the secreting tubes or calices of the kidney may exert what is known as a colloidal influence upon the forming crystals, modifying their shape or reducing the crystallisable material to a more or less amorphous and cohesive condition, in consequence of which they adhere together into masses or calculi. This alteration in the mucus may possibly, in some cases at least, be caused by the abnormal presence of crystals in the kidney, the two conditions thus acting and reacting on each other and combining in the production of calculus. That the mucous condition is a very important feature in the process is shown by the well-known experiments of Mr Rainey, followed by the observations of Dr Ord;[2] and it is maintained that without this colloidal influence the crystals have very little tendency to adhere together. Streaks of the granular or amorphous uric acid and of dumb-bells of calcium oxalate formed under this influence are not uncommonly found in the uriniferous tubes, especially in infants and young children, constituting the "uric acid infarction" of Virchow. Many years ago a medical man about sixty, of gouty diathesis and sensitive temperament, who

[1] See *Provincial Medical and Surgical Transactions*, vol. xvii.

[2] The Influence of Colloids upon Crystalline Form and Cohesion, 1879.

was liable to attacks of pain in a kidney, told me that after each attack he was conscious of something passing along the ureter into the bladder, and, being apprehensive of the formation of calculus, he used to watch on each occasion for the passage with the urine of what he called a "bleb of mucus." His apprehensions were realised, for after one of these attacks the looked-for "bleb" did not appear, a stone formed, and I subsequently lithotrised him. He recovered from this, but died subsequently from some kidney disease. When two or more calculi find their way into the bladder they usually, I believe, come from the same kidney; and in the *Transactions of the Pathological Society*[1] two instances are recorded by Dr Harley, in each of which numerous small calculi were found in one kidney (in one case in the left kidney, where they were of triple phosphate, and in the other instance in the right kidney, where they were of uric acid), the opposite kidney being quite free. Here the formation of the calculi evidently depended upon some peculiarity, probably in the mucous secretion, of the kidney. The importance of this view of the pathology of calculus, with regard to the investigation of the causes of the disease in particular districts, and to the measures to be taken for its prevention, must be borne in mind. It gives some support to the

FIG. 1.—Four nuclei in one calculus. (Cambridge collection.)

principle involved in Dr Yellowby's idea that the Norfolk dumplings and the indigestion resulting from them were *a* cause, if not *the* cause, of the prevalence of calculus in that county. The porous character of the nucleus, as compared with the layers formed upon it, which may often be observed, accords with its mucous origin. Two or more nuclei are not very infrequently found in a calculus. These are usually of uric acid or urate of ammonia. In this specimen (fig. 1) there are four nuclei; and in one in University College five uric-acid nuclei are embedded in a mass of phosphates, forming one large stone. In some instances they are small, and in some flattened by apposition. The junction of such may have taken place in the kidney, though I am not aware that renal calculi have been found with multiple nuclei. Now and then one sees two nuclei united by a band (as just mentioned) like Siamese twins and enclosed in a common envelope—indeed, a large number of small calculi may be united by phosphates into a single stone, as in a specimen examined by Dr Beale.[2] Occasionally, larger stones are thus joined together,

[1] *Transactions of the Pathological Society*, vol. xv. p. 147.
[2] *Urinary Deposits*, 1869, p. 419.

the uniting medium being commonly phosphatic, and two or more calculi, lying in apposition in the bladder, may become covered over and cemented by phosphatic material. In one specimen two good-sized, cone-shaped calculi, with their bases apposed but not in contact, are enveloped in a mass of porous, apparently phosphatic, material. In a specimen in King's College Hospital a small porous uric-acid stone is appended to, and united by phosphates with, a large, compact uric-acid stone which has an oxalate nucleus. The most remarkable example of such union is presented by the large seventeen-ounce calculus removed by Cheselden and represented in fig. 2, taken from

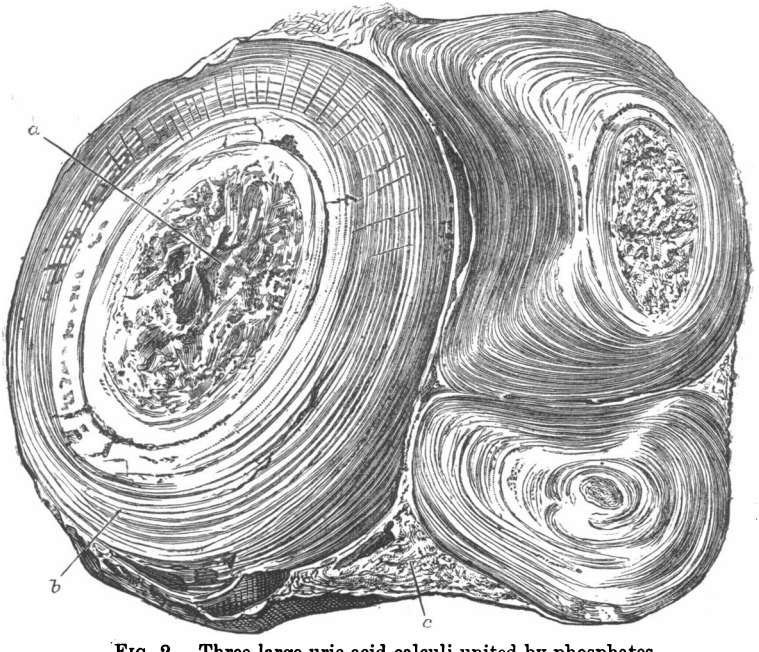

FIG. 2.—Three large uric-acid calculi united by phosphates.
(Catalogue of the Royal College of Surgeons.)

the catalogue of the Royal College of Surgeons of England (Plate III., fig. 1). In it three large uric-acid calculi, but little adapted to one another and not very closely approximated, are united by earthy phosphates. The central part of each of the three consists of porous uric acid or urate of ammonia, and the surrounding concentrically marked and more compact uric acid looks as if the calculi had lain in apposition, and that some shifting of them upon one another had taken place before they became united by the phosphatic deposit. The multiple nuclei are, as I have said, commonly composed of uric acid or urates. The oxalate calculi are usually single, and rarely have more than one nucleus; and, indeed, this material is seldom passed in the form of gravel. There is, however, in the museum in

Guy's Hospital a specimen in which four nodulated nuclei of oxalate of lime, as large as beans, are united by urates and surrounded by layers of uric acid, forming a large stone; and in the museum of the London Hospital there is a large calculus composed of two calcium oxalate calculi of unequal size enclosed in a mass of phosphates. When nuclei remain separate they form multiple calculi which, by apposition and mutual friction, commonly become faceted, and often in a manner rather difficult to account for. This, however, is not always the case. In the museum in Guy's Hospital there are sixteen calculi taken from a bladder after death; they are nearly as large as walnuts and are spherical and smooth on the surface. Here, also, are sixteen spherical, smooth calculi of rather smaller size. In the Norwich collection there is a large cuboidal calculus with four facets, upon each of which is applied a flattened calculus faceted on one side, the whole forming a nearly spherical mass which resisted the attempts to remove it by the lateral operation. The portions came away separately subsequently, through the wound, into the bed, but the patient did not recover.

When the nucleus or the calculus has reached the bladder it does not comport itself quite like an ordinary foreign body. The latter, as we know, whether it be a piece of bougie, a hairpin (as in this specimen), a mass of soap (as in two specimens in the Royal College of Surgeons of England), or any other substance, becomes encrusted with phosphates consequent on the irritation caused by it in the bladder, the only exception to this that I have known being the specimen in the Royal College of Surgeons of England in which a needle is the nucleus of a uric-acid stone; whereas a calculus usually increases by the addition of material like that of which it is composed. The reason of this difference must be that the calculus causes less irritation than a foreign body, which perhaps we should scarcely have expected. That a hairpin should be a source of considerable worry may easily be believed, but we should not have thought that a piece of bougie would have proved a greater irritant than a spinous oxalate calculus. True, the calculi may, and often do, become coated with phosphates. Usually, however, the addition to a calculus of uric acid, oxalate of lime, or cystine does not consist of phosphates, but of uric acid, oxalate of lime, or cystine, as the case may be. It is somewhat remarkable that this should be so, and should sometimes go on steadily for many years, as in the instance of the woman whose large stone I have shown you, in that of Sir Thomas Adams and in others, especially when we remember that oxalate of lime or oxalic acid and cystine are not commonly present in the urine at all, or indeed in the blood,[1] and that uric acid is present in small quantities, about six to ten grains only being passed in the four and twenty hours, and it does not exist in a free state in the urine, but is held in solution by an alkaline base from which it must be liberated before it can settle on a calculus.

Increase of calculi in size.—The addition to a calculus is probably

[1] Dr Beale found cystine continuously present for a long time in the urine of a young man who was otherwise healthy.—*Urinary Deposits*, 1869, p. 384.

effected by the same means as that by which the nucleus is formed—that is to say, by the influence of the mucus in the urine. This, where in contact with the stone and resting in the interstices of its surface, attracts, sets free, and modifies the uric acid, increasing its cohesive quality and causing it to settle upon the stone, and the quality of the uric acid thus added will depend upon the amount and quality of the mucus. When the latter is in small quantity the acid crystals will be little altered and will be slowly deposited, constituting the compact material of which the greater number of large, slowly forming calculi are composed. When the mucus is more abundant the uric acid is deposited in greater quantity, more quickly, and in more granular amorphous form and more irregularly, constituting the porous variety of which many stones are entirely, or in varying degrees, composed. The porous and the compact materials often vary in different periods of the formation of the same calculus, not infrequently succeeding one another and telling of successive periods of greater or less irritation of the bladder. The same remarks apply probably to the oxalate and cystine calculi, though variations in density in different parts of these are not so common as in those composed of uric acid.

Form of calculus.—Each variety of calculus takes its own form, the uric acid being oval and flattened (which is also commonly the case with the cystine), and the calcium oxalate being spherical. This cannot depend upon the surroundings, for the form differs in the two cases, and each assumes its particular form from the first—that is, when the stone is small. In the calcium oxalate the form may be given by the crystals radiating from the centre in needle-like lines and shooting out into the spines or tubercles on the surface; and in the uric-acid calculus it must likewise be some disposing property in its particles which gives the flattened oval shape, and which also causes the tubercles often seen on the surface and the lamination in its structure. Though the predominant form of the uric acid calculi is a flattened oval, especially when the substance is compact, it is liable to great varieties.[1] Often it is prolonged in certain directions by the deposit upon it of the porous uric acid or urate of ammonia, or of the two combined, the particles of which, being more or less deprived of their crystallising quality, lose proportionately their form-determining property. It not uncommonly happens that the calculi are prolonged at one or both ends of the oval; and in Sir Henry Thompson's cabinet in the Royal College of Surgeons of England there is the curious instance of a square-shaped calculus in which the four angles have been prolonged by porous uric deposit upon each, the whole being covered over by more compact uric acid, as though, for a given and short period, the irritation of the bladder by the four corners had determined the presence of mucus upon them, with the consequent porous condition of the uric acid. Occasionally, as in the specimen represented in fig. 3 from the catalogue of the

[1] They may be nearly spherical in shape, as is the 8 oz. calculus mentioned above; and Mr Vincent Jackson, of Wolverhampton, tells me he has a spherical uric-acid calculus in his possession.

Royal College of Surgeons of England, a uric-acid calculus is capped at one end with a thick layer of compact striated uric acid. The smooth groove on the surface between the two parts in this stone has suggested that the one part may have been formed in a cyst and the other part in the bladder, but, in addition to the fact that encysted calculi are usually phosphatic, there is a specimen in the College in which there is a similar cap at each end. A calculus in the museum at St Mary's Hospital has a small cap of the like material at one end,

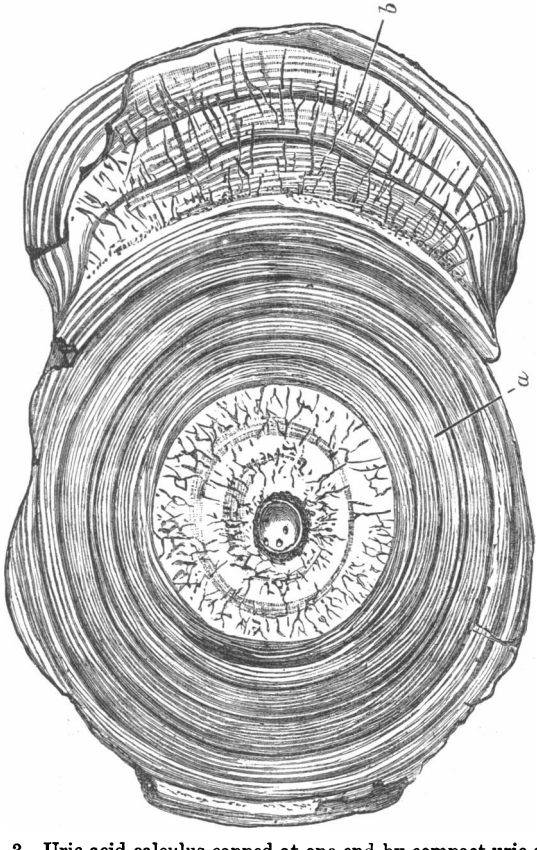

FIG. 3—Uric-acid calculus capped at one end by compact uric acid. (Catalogue of the Royal College of Surgeons.)

and the whole is covered with a layer of phosphate. A specimen in Sir Henry Thompson's cabinet looks as if a number of small uric-acid calculi had settled upon and adhered to an elongated stone of the same material, this being, I suppose, in reality, an exaggeration of the granular or tuberated condition not uncommon in uric-acid calculi. The nucleus may be at one end, the calculus having been

prolonged in the opposite direction into a finger-like form by compact or porous uric deposit, as in this specimen. Here is a triangular flattened calculus; and in a specimen in the museum at St George's Hospital a calculus has acquired an hour-glass shape from increase at both ends, the nucleus being in the middle. This, I should say, is thought to have been due to the solution of the middle part by the urine, which can scarcely have been the case, for the calculus presents the same smoothness and character of contour over its whole surface. Such constrictions or grooves dividing a calculus into two or more equal or unequal parts are occasionally seen (fig. 4), and they are commonly attributable to projections into the bladder of the hinder edge of the trigone or some other bands which have impressed the calculus. They are generally smooth, as smooth as, or smoother than, other parts of the surface of the calculi. Occasionally, but more rarely, the constriction has been caused by the formation of one part of the stone in a cyst and of the other part in the bladder

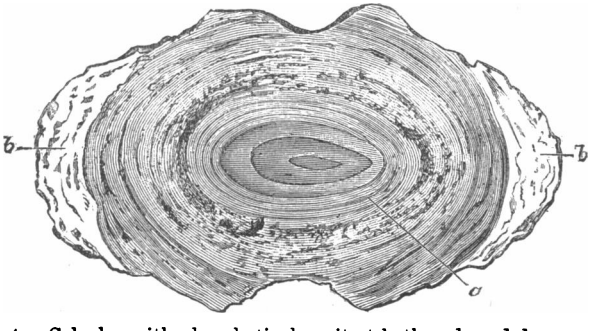

FIG. 4.—Calculus with phosphatic deposit at both ends and deep groove in the middle. (Cambridge collection.)

and represents the narrow orifice of communication between the bladder and the cyst. In such cases, as I have said, the calculi are, so far as I have seen, phosphatic.[1] Various forms are given by the addition of lime salts, and it is to be remarked that these are often deposited upon the ends of the oval uric-acid calculi, extending their long axes and leaving the rest of their surfaces

[1] There has been lately added to the museum at Cambridge the bladder, with cystitis and thickened wall, from a lad who died in Addenbrooke's Hospital. The ureters were dilated, and there was hydronephrosis on both sides. On the left side of the bladder, near the entrance of the ureter, but separate from it, are two small orifices of sacculi, each of which was filled by a phosphatic calculus nearly the size of a walnut, of hard structure and with concentric laminæ. These two sacculi displaced and stretched the ureter, and must, in some degree, have obstructed the passage of urine through it. On the right side, also near the ureter, but not interfering with it, is a small sacculus which did not contain a calculus. There was no calculus in the bladder, and it is not easy to decide what determined the formation of the sacculi and the formation of the calculi in the two sacculi on the left side. Still more recently a specimen has been added of enlarged prostate, with numerous small calculi lodged in sacculi, or, rather, fasciculated depressions in the bladder.

uncovered, of which fig. 4 is an illustration. Does this indicate that the salts have a tendency to settle upon the ends or more prominent parts of the calculi, as in the instance of the square uric-acid calculus before mentioned, in which a collection of porous uric acid is seen in each of the four corners? This large calculus, the other half of which is in St Bartholomew's Hospital, is partially covered by thick, defined, irregular bands of phosphates, the intervening parts of the surface being free. The cause of this irregularity in the deposit I cannot tell. The calcium oxalate calculus is less liable to varieties of form than the uric acid, perhaps because the needle-like radiation of its crystals is a more determined factor, and leads to the more definitely spherical shape. In Guy's Hospital, however, there is a square calculus of this material, also a cast (I believe) of one which is elongated, one of large size marked by a deep groove, and others of different shapes. In the museum of St Thomas's Hospital there is an example of several faceted calcium oxalate calculi quite smooth on the surface and nearly colourless, both these peculiarities being very rare, for this variety of calculus is usually single and dark-coloured. In that museum also is an instance in which knobs of oxalate have formed upon a uric-acid calculus.

Concentric and radial fissuring and fragmentation of calculi.—There is in the uric-acid calculi, evinced more particularly when they have become dry, a tendency to crack into layers and also to split radially, such as may be seen in the transverse section of the branch of a tree. This probably depends upon the concentric and radially fibrillar arrangement of the particles of the calculus, resembling that which was noticed by Mr Rainey in the small calcium carbonate spheres resulting from the action of gum upon ammonium carbonate. It facilitates probably the breaking up of the stone under the lithotrite, and may possibly, under certain conditions, such as some change in the cementing material of the calculus, lead to the spontaneous division of the stone into fragments in the bladder. A supposed example of this is represented in Plate XII., fig. 10, of the catalogue of the Royal College of Surgeons of England, taken from a specimen in the museum at St Bartholomew's Hospital, in which a portion of the outer layer of the calculus has become detached. One cannot but suspect that such a fragment may have been broken off in sounding. There do not appear to be any other fissures in the calculus, and it is difficult to see how it can have been spontaneously detached in the bladder. The same remarks apply to the two cases mentioned by Mr Southam;[1] and in the third case, communicated to him by Mr Luke, the lithotrite had been used and the stone had twice slipped from under it. Instances of supposed spontaneous disintegration of calculi are also given by Dr Ord.[2] Mr Coulson[3] mentions a case in which fragments of the shell of a medium-sized uric-acid calculus were spontaneously detached and passed from the bladder. The

[1] *Brit. Med. Jour.*, Jan. 4th, 1868.
[2] *Op. cit.*, p. 93.
[3] *Transactions of the Pathological Society*, vol. xv. p. 143.

detachment was judged to have been caused by the violent contact of two stones during severe attacks of bladder irritation.[1]

Colour and concentric colour-markings.—Each variety of calculus acquires its particular colour. The uric acid attracts the urochrome of the urine, which gives it, whether in the form of gravel or stone, a reddish-brown or fawn colour. Owen Rees is said to have seen one perfectly white.[2] The dark colour of the calcium oxalate has been attributed to an admixture of the colouring matter of the blood; but its uniform diffusion seems rather to point to its depending upon some modification of the colouring matter of the urine which takes place during the formation of its crystals. I have already mentioned an instance in which the colour was absent. The oxalate so rarely passes as gravel that we have not much opportunity of determining its colour under those circumstances. The disposition of the colour in alternating deeper and fainter lines shading into one another, and giving the concentric markings common in compact uric-acid calculi, is not quite easy to account for. The lines are usually in complete circles, though varying in depth and definiteness in different parts of the circumference, and in different parts of the thickness of a calculus. Yet in this thirty-two-ounce stone they have evidently been formed in fairly regular order through many years. Such colour-markings are by no means peculiar to uric-acid calculi. They are sometimes seen faintly in the oxalates and in the harder phosphates, though in the latter they may have relation to admixture with uric acid or calcium oxalate in certain of their layers. They may be discernible in gall-stones, and are often strongly marked, as in this specimen, in the stones composed mainly of carbonate of lime, found in the intestines of horses, and also in other instances. Are we to suppose, in the case of uric-acid calculi, that they depend upon alternating changes in the urine which indicate subtle changes in the system not otherwise evinced, such as might be caused by changes of food, changes of temperature as in the rings in trees, or other influences? They are not numerous enough to be diurnal, and they are too numerous to be annual. Or do they depend, like the concentric rings in bone, which exhibit, and are caused by, the arrangement of the bone corpuscles, upon some determining quality in the material itself? The frequently-occurring calculi in which layers of compact and porous uric acid exist in super-imposed layers, with varying amounts of urate of ammonia, also the "alternating calculi" composed of uric acid, calcium oxalate, and phosphate of lime occurring and recurring in varying layers, must depend upon corresponding changes in the urine, and form an argument in favour of the former hypothesis. At any rate, a question of some interest in pathology and physiology is opened up by these markings and other alternations observable in calculi.

I have mentioned that the more porous uric-acid substance differs from the compact in the greater contingent of mucus, which gives to

[1] See also "Case of Spontaneous Fracture of Uric Acid Calculi," by Dr Plowright, and discussion at a meeting of the *Pathological Society of London*, in *The Lancet* of Oct. 19th, 1895. [2] Ashhurst, *loc. cit.*, vol. vi. p. 165.

it a more or less granular or amorphous character, and that it does not acquire the regular colour-markings just described. It does, however, often present a radially coarse fibrous structure with traces of concentric layers. In this specimen (figs. 5 and 6) the radiating bars are crossed and connected by tiers of concentric strata; and the two have the effect of dividing up the calculus in such a manner as to

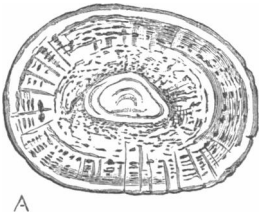

FIG. 5.—Porous uric-acid calculus, showing radial and concentric disposition of fibres. (Cambridge collection.)

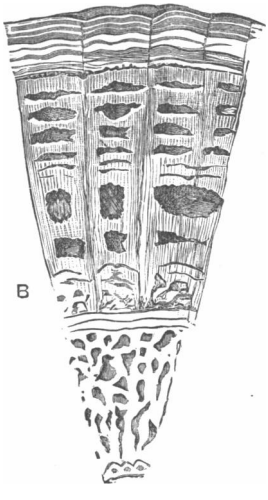

FIG. 6.—Section of above, magnified, showing more or less rectangular chambers enclosed by the radial and concentric fibres.

enclose regular squares or elongated spaces or small chambers with defined walls and angles. How the curious arrangement came about I cannot tell. The porous calculi usually conform to the flattened oval uric-acid type, and when the porous is added to the compact uric acid it commonly does the same; but, as I have before said, it may be limited to some part or parts of the surface, perhaps to the more projecting parts, as the ends, and give in that case an elongated form to the calculus.

Erosion of calculi in the bladder.—I have not been able to satisfy myself of any clear evidence of the solution or erosion of calculi in the bladder. The grooves on the surface often attributed to that cause are usually smooth and crescentic, or circular, and are obviously due to the projection of rugæ or bands from the internal surface of the bladder, which have interfered with the deposit upon the stone where they embraced it. The calculus is not uncommonly thus modified, acquiring an hour-glass shape, or being constricted in various ways. The hinder edge of the trigone, as seen in Sir Thomas Adams's stone, may be the cause, or the pressure of the urethral orifice upon a calculus which projects into the more yielding prostatic part of the urethra. These supposed evidences of erosion are most common in compact uric-acid calculi, which one would not judge most likely to undergo solution. The coloured rings may now and then be seen to be incurved at the grooves, but they more commonly stop short and terminate in rounded ends at the margins of the grooves (as seen in fig. 4); or they may terminate even more abruptly so as to give some countenance to the erosion theory, not, however, enough to counterbalance the facts that the grooves are smooth; and in some instances, even where the rings terminate, as I have mentioned, the grooves are known to have been caused by constricting bands, and the remainder of the surface of the calculus gives no indications of a solvent action. Further, in some a coating of deposit, uric or phosphatic, has formed over the whole surface, including the grooves, which scarcely accords with the view of erosian of any part. The rough, sharply-defined depressions or holes seen upon some calculi are more suggestive of erosion, but they probably depend upon irregularity in the phosphatic or other deposit rather than upon erosion. There is in the museum at St Thomas's Hospital a large uric-acid calculus resembling that from Sir Thomas Adams, and with a similar constriction or groove. The exterior is described as being "water-worn and the colour washed out." It presents to me more the appearance of being coated with a layer of rather lighter material than the rest of the stone, intermixed probably with some phosphates, which had been deposited in an irregular or tuberculated manner, so as to give the impression that the surface had been acted on by the urine or "water-worn." One is rather at a loss to know by what ingredients in the urine the solution, whether of uric or phosphatic calculi, could be effected. It is possible that certain changes in the urine, acting upon the cementing material of the surface of the calculus, as suggested by Dr Ord [1] with reference to the disruption of calculi, might lead to the removal of particles which pass away with the urine; but the whole subject is, I think, still *sub judice*.

Phosphatic calculi.—Phosphatic calculi do not assume any regular or special form, like the uric or oxalate calculi. When added on to other calculi, the phosphatic concretion commonly continues the form of that upon which it is laid, or, as I have already said, it may prolong it in certain directions or be deposited in various ways;

[1] *Op. cit.*, p. 97.

and it is said not to possess the property of cohering into a calculus or upon a calculus, except in the presence and under the colloidal influence of mucus or pus. In the museum at St Mary's Hospital there is a uric-acid calculus with phosphatic deposit on one side only, as though the stone has rested quietly on one surface in the bladder and the phosphates had been limited to the uncovered or exposed part. In that museum is also a curious pyriform phosphatic calculus composed apparently of eight faceted pieces accurately adapted to one another; and a finger-like process which extended into the urethra is marked off from the remainder by a deep constricting groove formed by the neck of the bladder. It was taken after death from a man who had for many years suffered from the effects of fracture of the spine. In the same museum there are also two disc-shaped faceted phosphatic calculi of the size of beans, removed from the phimosed prepuce of an old man who died from hydronephrosis. They are said to have caused retention of urine. It is often stated that phosphatic deposit, being due to inflammation of the bladder and consequent decomposition of the urine, is a final deposit upon a calculus and is not followed by any other material. This, however, is disproved by numerous specimens in which rings of uric acid and calcium oxalate are seen encircling the phosphatic formation or alternating with it. In some examples the alternating and waving disposition of the oxalate presents a variegated and pretty section, not unsuitable, as was remarked to me, for a lady's brooch. In an example at the Royal College of Surgeons of England a phosphatic calculus with a considerable projection at one part is encircled by a waving line of calcium oxalate. In these cases the phosphate is usually compact, indicating that the bladder inflammation upon which it depended was not very severe. I do not think that the looser, softer phosphatic substance, the result of more active inflammation, is followed by other deposit—at least, I have not met with an instance in which it was so.

Bone, teeth, and hair in the bladder.—These portions of bone with teeth and hair, covered with phosphate of lime, I removed through the urethra from the bladder of a woman who quite recovered from the operation. The finger introduced into the bladder did not discover any other disease. The supposition is that the masses originated in the ovary, probably in a congenital cyst, and found their way into the bladder, after the manner in which an extra-uterine fœtus—or the bones of one—occasionally travels into the rectum. In University College there is a phosphatic calculus elongated at one end where there is a fœtal tibia which formed the nucleus of the stone. After the death of the patient other remains of a fœtus were found in the right iliac fossa. Dr Beale[1] mentions an instance in which hairs that have escaped from an ovarian cyst into the bladder formed the nuclei of calculi; and gall-stones are said to have been passed from the urinary bladder, having found their way into that viscus in consequence of a communication found between it and the gall-bladder.[2]

[1] *Urinary Deposits*, 1869, p. 419. [2] Ashhurst, *loc. cit.*, vol. vi. p. 164.